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Studying Transition Region Phenomena with Solar-B/EIS

Abstract. Transition region lines in active regions can become strongly enhanced in coronal footpoints and active region blinkers. The weak transition region lines found in the Solar-B/EIS wavebands will thus become useful for diagnostic studies of these events. EIS count rates predicted from SOHO/CDS spectra are presented, and a Mg VII density diagnostic is highlighted.

1. Introduction

The EUV Imaging Spectrograph (EIS) on Solar-B will provide high resolution EUV spectra over the wavelength ranges 170–210 Å and 250–290 Å where there are many strong emission lines from coronal species, particularly the iron ions Fe X–XVI. Strong transition region lines in UV are found only above 400 Å, however, and thus only weak lines are found in the EIS wavebands. Table 1 lists the most important of these lines together with their temperature of maximum abundance ($T_{\max}$). The following sections use data obtained with the Coronal Diagnostic Spectrometer (CDS) on SOHO to show that these transition region lines can become strong in certain active region features and will complement the coronal line data.

Table 1. Key transition region lines that will be observed by EIS.

Ion	Wavelength/Å	Transition	Log $T_{\max}$/K
Mg V	276.58	$2s^2 2p^4\ ^1D_2 - 2s2p^5\ ^1P_1$	5.5
Fe VIII	185.12	$3p^6 3d\ ^2D_{5/2} - 3p^5 3d^2\ ^1P_1$	5.6
Mg VI	268.99	$2s^2 2p^3\ ^2D_{3/2} - 2s2p^4\ ^2P_{1/2}$	5.7
	270.40	$2s^2 2p^3\ ^2D_{3/2,5/2} - 2s2p^4\ ^2P_{3/2}$	5.7
Mg VII	278.39	$2s^2 2p^2\ ^3P_2 - 2s2p^3\ ^3S_1$	5.8
	280.75	$2s^2 2p^2\ ^1D_2 - 2s2p^3\ ^1P_1$	5.8
Si VII	275.35	$2s^2 2p^4\ ^3P_2 - 2s2p^5\ ^3P_2$	5.8

2. Density diagnostics

EIS has excellent density diagnostic capability at coronal temperatures, with several line ratio diagnostics with strong sensitivity to density. There is also one diagnostic below 10^6 K: Mg VII 280.75/278.39 formed at $\log T = 5.8$. Figure 1 shows the sensitivity of the ratio as a function of density derived from v5.1 of the

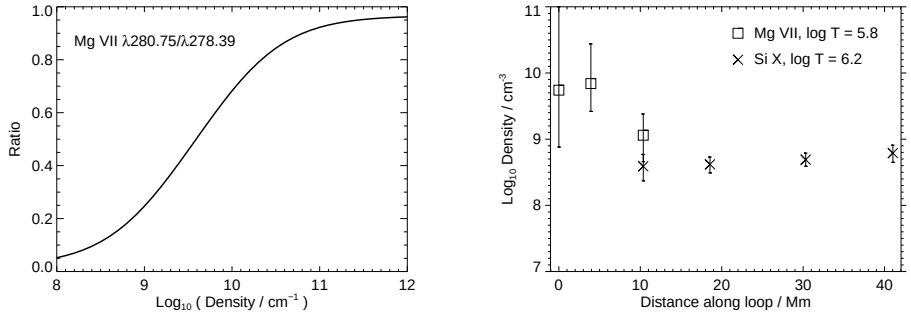

Figure 1. The left-hand panel shows the density sensitivity of the Mg VII 280.75/278.39 ratio. The right-hand panel shows density measurements from Mg VII obtained with CDS coupled with Si X density measurements, illustrating how Mg VII is used to probe the footpoint regions of the coronal loop discussed in Sect. 3..

CHIANTI database (Landi et al. 2005). Care has to be taken with the λ278.39 line as it is blended with Si VII λ278.44, however this can be accounted for if the Si VII λ275.35 line is observed, since the Si VII λ278.44/λ275.35 ratio has a value of 0.32 in all solar conditions.

The value of the Mg VII ratio is illustrated in Figure 1, where density measurements obtained with CDS in the coronal loop discussed in Sect. 3 are presented. Mg VII is used in the loop footpoint where the coronal diagnostics are not useful.

3. Coronal loop footpoints

Coronal loops observed with CDS often show bright emission in upper transition region lines at their footpoints. They are particularly strong in lines of Mg V, Mg VI and Mg VII. Emission lines from these ions are also seen with EIS, and we can directly estimate emission line strengths for EIS based on the CDS spectra.

Table 2. CDS line intensities from the loop footpoint shown in Figure 2 are given for four magnesium ion lines. Using the CHIANTI database, the intensities for lines of the same ions that appear in the EIS wavebands are predicted, and the event rates at the detector are given. These are compared with average active region event rates.

	CDS lines		EIS lines			Average
Ion	λ [Å]	Intensity [erg/cm^2/s/sr]	λ [Å]	Intensity [erg/cm^2/s/sr]	Signal [DN/s]	Signal [DN/s]
Mg V	353.2	561	276.58	309	14.7	1.1
Mg VI	349.2	812	270.40	487	29.8	6.6
Mg VII	367.7	585	278.39	450	18.3	3.3
	319.0	602	280.75	331	10.5	5.9

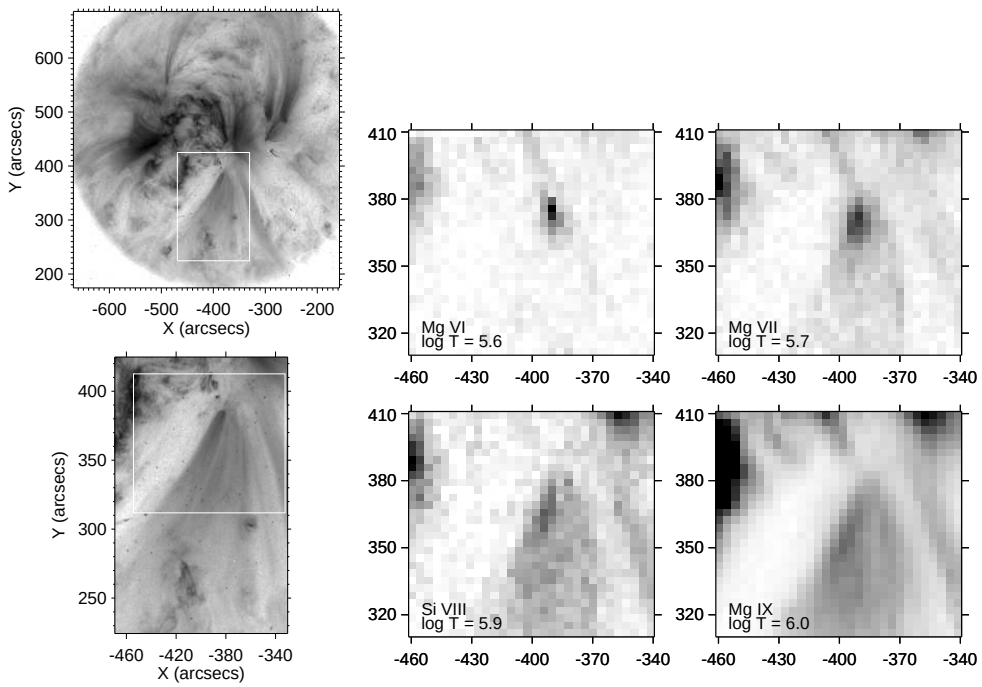

Figure 2. The upper left panel shows a TRACE 173 image of active region AR 8227 observed on 1998 May 29, with the white box indicating the region shown in greater detail in the lower left panel. The white box in this image shows the region observed with CDS, from which four images are shown in the right hand panels. These four images show the loop at different temperatures, with the footpoint clearly seen in Mg VI and Mg VII. The images are shown as negatives with the most intense regions coloured black.

The images in Figure 2 show one particular isolated loop, where the CDS data show the footpoint to be bright in the cool Mg ions. Intensities from CDS are given in Table 2, together with intensities for the EIS lines predicted from the CDS lines using atomic data from CHIANTI. The intensities are then converted to data numbers (DN) per second, and compared with average active region values showing the large enhancements found in the footpoints.

4. Active region blinkers

Blinkers are flashes in the transition region, first studied with CDS (Harrison 1997). In active regions, the intensities of blinkers can be factors 10^3–10^5 higher than in the quiet Sun and have densities up to 10^{12} cm^{-3} (Parnell et al. 2002; Young 2004). They appear to be related to new flux emergence and have photospheric abundances (Young & Mason 1997), being particularly pronounced in emission lines of Ne and O. An example from CDS is shown in Figure 3.

As with loop footpoints, the Mg V–VII lines are strongly enhanced in these blinker events, however the blinkers are usually found in the central part of active regions where coronal lines are strong. Studies with CDS were thus compromised

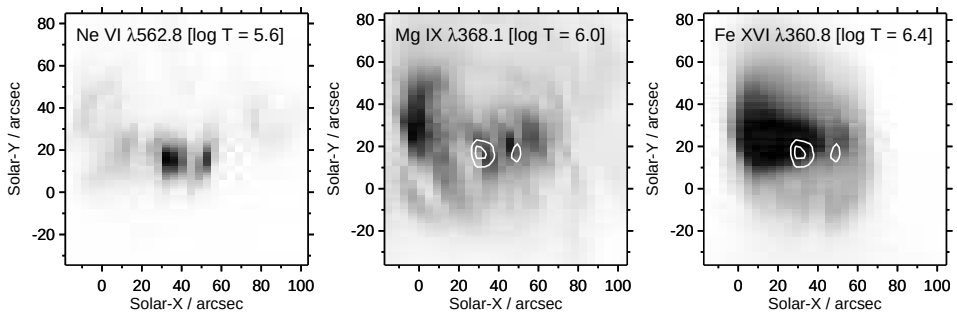

Figure 3. Images of active region AR 7968 obtained on 1996 June 6 by CDS. The Ne VI image shows two short-lived active region blinkers near the centre of the raster. The locations of these brightenings are superimposed on the two coronal line images through contours and show that they found in the central part of active regions. The images are shown as negatives with the most intense regions coloured black.

by significant blending with coronal lines. This will not be a problem with the higher spectral resolution of EIS, while the higher spatial resolution of EIS will concentrate the blinkers into 1 or 2 spatial pixels, leading to higher photons/pixel than found with CDS.

5. Conclusions

Weak transition region lines in the EIS wavelength bands will provide extremely valuable science in studies of active regions. The coolest ions (Mg V, Mg VI, Fe VIII) will highlight coronal loop footpoints: of great benefit when combining with the photospheric/chromospheric data from SOT. The Mg VII density diagnostic will provide a density measurement in these footpoint regions.

Active region blinkers will be seen in the transition region lines, and the high spectral resolution of EIS will allow the relationship with explosive events to be understood. Again by coupling with the SOT data, the precise relationship between these blinkers and the magnetic field evolution can be determined.

Scientists are strongly encouraged to include one or more of the cool lines discussed here when designing EIS studies.

References

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